BTEV Expression of Interest in C0

Various names go here
with institutions

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Abstract

We propose to use the C0 interaction region to develop a prototype of the BTEV detector – a second generation detector to perform in-depth studies of CP violation and rare B and charm decays. We will use this 'proto-detector' to validate the key components of BTEV and to undertake a series of physics measurements which will be of interest in their own right but which will also provide an opportunity to analyze data taken under realistic conditions in the forward direction at the Tevatron.

1 Introduction

This letter expresses the interest of the "BTEV" group to use the C0 interaction region to make a systematic sequence of detector studies and physics measurements. These will provide an evolutionary path to the development of a full detector for the study of CP violation and the search for rare B and charm decays. A sketch of a "baseline" BTEV detector is shown in figure 1. We will attempt to create a situation in C0 which approximates this detector as closely as possible (but on a smaller scale) . In this way, we can test each critical component of the final detector before embarking on producing the final, full-scale system. We will also be simultaneously developing our ability to analyze data taken under realistic conditions in the collider. This will assure us and Fermilab of a sound design and solid analysis capability at the startup of BTEV.

We propose the following broad phases for our activities:

Phase 0: Initial R&D

This is the preparatory phase. It involves R&D in pixels and triggers. It also includes the creation through detailed simulation of an optimal design of BTEV and of the C0 detector and an understanding of the relation between them. Finally, it includes design studies of RICH detector systems for particle identification.

Phase 1: Beam Tests in C0

We need to install enough equipment in C0 to test the basic concepts of BTEV triggering. The key to this test is a silicon strip and pixel based system with a DAQ system that could be a DART system recovered from fixed target. The silicon goes inside the beampipe and is also surrounded by a large dipole magnet. We also require a muon system in the forward direction.

The trigger tests would be two-fold. One test (which would be done first because it can be run completely with no effect on CDF and D0 operation) would use a wire target in the beam halo to produce interactions. We could compare vertex based triggers on charm decays with charm extracted from a muon-triggered sample. In collider mode, we can calibrate the trigger efficiency and rejection using charm decays collected with a minimum bias trigger because the charm cross section is enormous. Also, in collider mode, we can compare B decays into ψ using a dimuon trigger with the the vertex based trigger.

In collider mode, we can also study backgrounds (from collisions and from stuff hitting the low beta quads) that will be relevant for BTEV. If there is even a small prototype EM calorimeter, we can study the feasibility of γ, π^o measurements in the collider.

Phase 2: Further Tests and Physics studies in C0

A series of physics measurements which includes studies of charm meson decays and the observation of B-meson decays will be undertaken. These will provide substantial datasets which, in the case of charm, will have real physics interest. Topics to be addressed are D^o mixing, CP violation in charm meson decays, and search for rare and SM forbidden decays. B-physics topics include the study of moderate size samples of B^o, B^+, and B_s decays. These datasets are crucial for understanding trigger and tracking issues as well as for teaching us to deal with the various backgrounds present in the Tevatron. In fact, the goals of phase 1 and 2 are closely related and it is likely that the experiment will alternate between specific studies and physics runs. The ability to do competitive physics will depend on having a well instrumented detector – one that certainly will go beyond the barest requirements of the trigger studies.

2 B Physics in BTEV and in C0

It is well known that B physics is extremely interesting and exciting because both Standard Model parameters can be measured and physics beyond the Standard Model can possibly be observed. The most interesting SM model physics can be summarized in terms of the Bjorken (or CKM) triangle. One side is defined as unity, one side is given by measurements of V_{ub}/V_{cb}, while the 3rd side can be measured from the ratio of B_s/B_d mixing parameters. The three angles, α, β and γ, are found from three independent CP asymmetry measurements. Any inconsistency found in sides or angles would point to new physics. Of course, the demonstration of such an inconsistency, even taken together with what is known about the lengths of the sides of the triangle, requires reasonably precise measurements of all three angles.

The current situation is summarized in figure 2. Constraints on the CKM matrix parameters ρ and η are shown from measurements of V_{ub}/V_{cb}, B^o mixing and ϵ in the K^o system. Also shown is the excluded region from LEP measurements of x_s. While the measurements currently are consistent, reflecting the success of the standard model, more precision is needed in the measurements of the sides of the triangle and the angles have not been measured at all. Since the error in the side determined by B^o mixing comes dominantly from theoretical predictions of f_B, the best way to reduce the width of this band comes from measuring B_s mixing; f_{B_s}/f_B being predicted with small error.

In our opinion the asymmetric e^+e^- B factories (KEK and SLAC) will successfully make the first measurement of CP violation in the ψK_s mode (CDF may also measure an asymmetry in this mode), or show that CP violation in this mode is much lower than standard model expectations. They and the symmetric Cornell B factory may also see signs of CP violation in charged

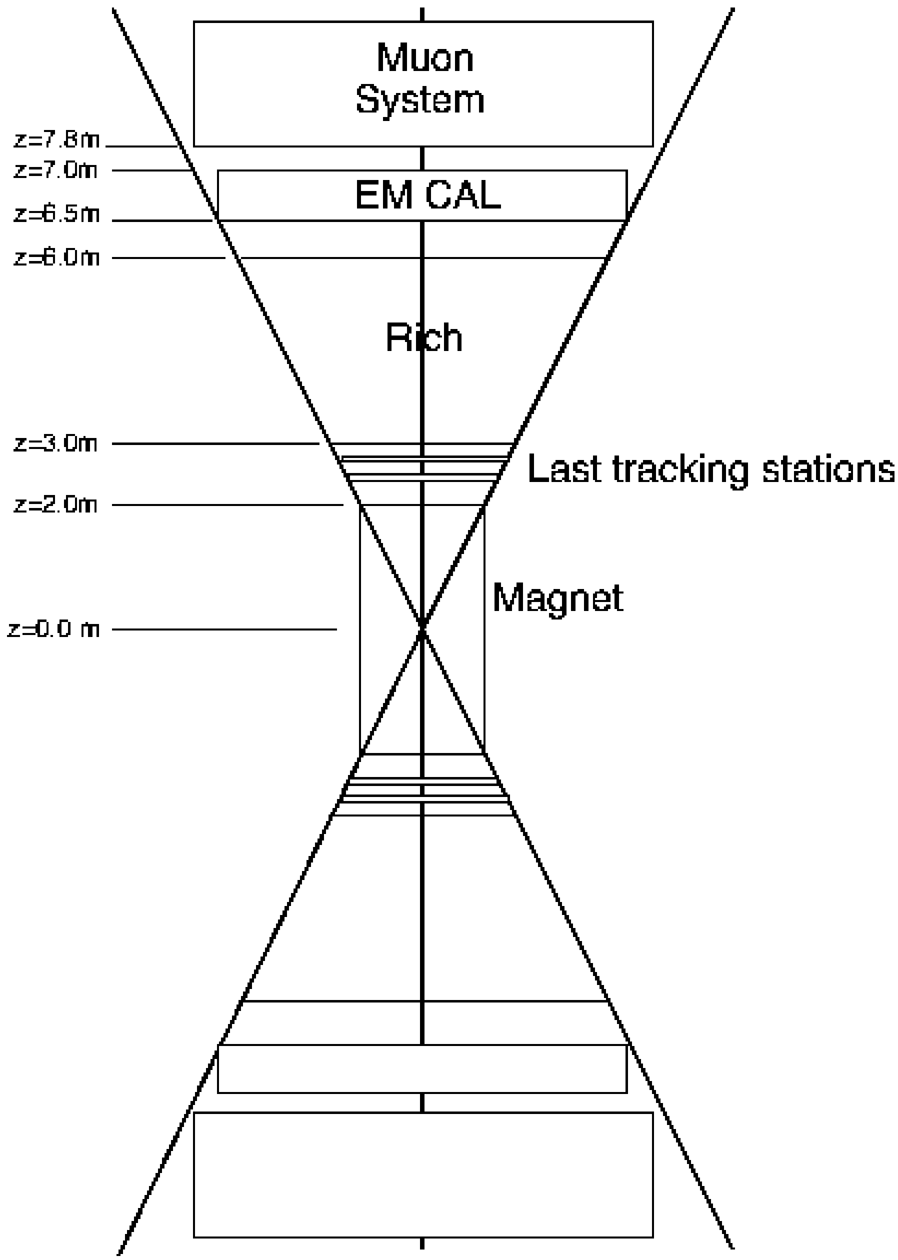


Figure 1: Schematic Layout of BTEV Detector (Vertex Detector not shown)

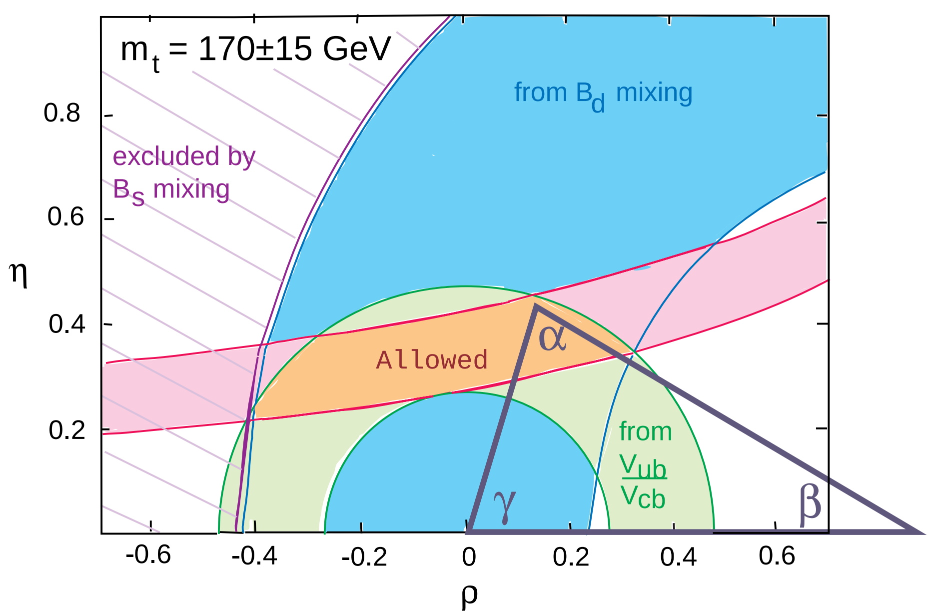


Figure 2: Unitarity triangle showing existing constraints on ρ and η

B decays. However, measurements of CP asymmetry in the important $\pi^+\pi^-$ channel and B_s mixing are beyond the scope of these machines.

To justify our pessimism in the $\pi^+\pi^-$ case requires looking only at the SLAC and KEK proposals [1]. SLAC assumed a branching ratio of 2x10^{-5} while the current CLEO measurement indicates 1x10^{-5}. Furthermore they assume that they can use the $\rho^+\pi^-$ ($\rho^-\pi^+$) channels, with a 3 times higher branching ratio (KEK made similar assumptions). CLEO finds that these channels are background dominated and thus cannot measure a branching ratio. Even if the background problems can somehow be overcome there is another problem due to the addition of Penguin diagrams to these decays (the asymmetry can arise not only from the coherent addition of the mixed and unmixed amplitudes.) To extract the angle α from asymmetry measurements in these channels requires the measurement of many other modes such as $\rho^o\pi^-$, $\rho^o\pi^o$, etc.. [2]. Since the $\rho^+\pi^-$ ($\rho^-\pi^+$) branching ratio was assumed to be 3X higher than $\pi^+\pi^-$, the lower $\pi^+\pi^-$ branching ratio and the loss of the $\rho^\pm\pi^\mp$ channel lowers the expected number of events from the proposals by a factor of 6, making a measurement of the CKM angle α highly unlikely [3]

[4], while in BTEV the asymmetry measurement for $B^o \to \pi^+\pi^-$ is sufficient to measure α provided that the branching fractions for $B^o \to \pi^o\pi^o$ and $B^- \to \pi^o\pi^-$ are measured in e^+e^- machines.

The claims of being able to measure B_s mixing at the $\Upsilon(5S)$ assume x_s is relatively small. The Cornell B factory proposal analyzed the possibilities of measuring x_s using an asymmetric machine [5]. They show that they may be able to reach $x_s \sim 4$, and state "One may be able to access slightly higher x_s values via the time dependent technique with a more asymmetric machine and more precise vertex detection, but oscillations with $x_s > 6$ may be experimentally unobservable with any asymmetric collider." We note that the current limit from LEP is > 12 [6]. Current plans at SLD are to extend the reach to 15. We have already documented the excellent possibilities of measuring Bs mixing with BTEV using $B_s \to \psi K^*$ [7].

HERA-B, if it is successful, will only measure the ψK_s mode. Thus we will be left with the most of the most interesting B physics to be done. This includes measurement of α, B_s mixing and γ. The latter can be done without theoretical ambiguity by measuring the modes $B^- \to D^o K^-, \overline{D}^o K^-$ and $D^o_{cp} K^-$[9]. This can only be done in e^+e^- if both the strong and weak phase shifts are near 90^o[10]. In addition, rare decays such as $K\ell^+\ell^-$, $\mu^+\mu^-$ and other modes, and CP violation in these modes will be left untouched as the branching ratios are in the 10^{-7}-10^{-8} range. Other more mundane issues such as V_{cb} and V_{ub} can be addressed by baryonic decays such as $\Lambda_b \to \Lambda\ell\nu$, which cannot be done by the e^+e^- machines or HERA-B.

The conclusion we come to is "that the first generation of experiments will open up the field of study of CP violation in B decays but will not close it".

The only competition we are left with is LHC-B. In fact, we believe that BTEV, because of its aggressive triggering and tracking strategy, will be a significantly better experiment than LHC-B for the very states that will be most interesting after the results from the B-factories and other experiments running around the year 2000 are in. In particular, LHC-B has rather low triggering efficiency on many interesting states which contain only hadrons whereas BTEV has efficiencies in many cases approaching 50% of all the events where the B fragments are within the spectrometer's acceptance. We believe that a competition between Europe and America in B physics would be highly beneficial. We believe that the importance of B physics has not been clearly stated. In our opinion, physics beyond the standard model could as easily be found in B decays as in high p_t physics at LHC. Furthermore, this is an area where Fermilab can compete in the LHC era.

3 Motivation for B Physics in the Forward region at the Tevatron

The detector operates in the "forward" kinematic region, complementary to the existing collider detectors at Fermilab which work in the "central" region. There are several advantages to this configuration. The kinematics of b production at the collider are such that the b's have a mean p_t of about 5 GeV/c while they are almost evenly spread longitudinaly in η, and thus peaked forward in $cos(\theta)$. Since B flavored hadrons decay in multiparticle final states, the transverse momenta of the decay products, while higher in mean than mimimum bias events, are still quite limited. The most potent method of selecting B's at hadron colliders is to see a detached vertex formed of tracks from the B decay products. This can be used for all B decay modes, unlike a dimuon trigger, for example, which is effective at finding $B \to \psi X$ decays.

In the central region, the B's have small longitudinal momenta (those at $\eta = 0$, have none), but in the forward direction there is large longitudinal momenta. The most important consequence of this momenta is that the B decay tracks suffer small multiple scattering errors, thus allowing precision verticizing. In Fig. 3 we show decay length distribution divided by the error in decay length, L/σ, for the decay mode $B^o \to \pi^+\pi^-$ simulated in a forward and central detector [8]. We see that it is far easier to select events in the forward detector. While the central detector has events with large L/σ values many are close to zero and would be lost with tight cut. More evidence is given by the time resolution found for the decay $B_s \to \psi K^*$, $K^* \to K^-\pi^+$, which has been suggested as a way of measuring B_s mixing [7]. Time resolutions for both forward and central detectors are shown in Fig. 4. The time resolution is a factor of 10 better in the forward detector than in the central detector. Part of this improvement is that the forward geometry allows placement of the silicon vertex detectors inside the beam pipe which eliminates the material in the beam pipe for verticizing and allows the detectors to be close to the beam.

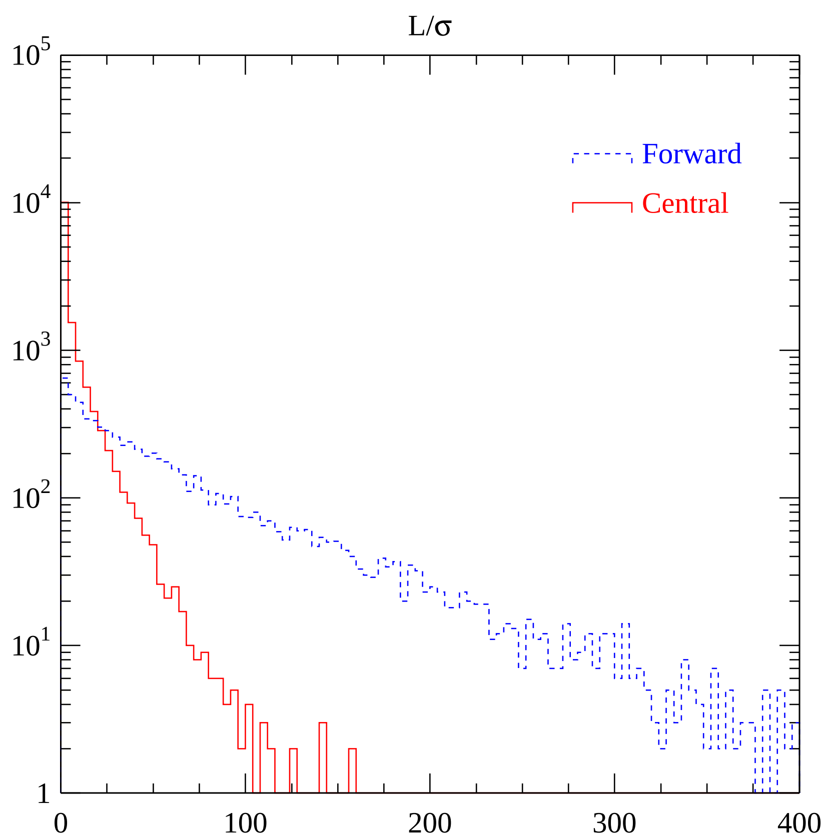
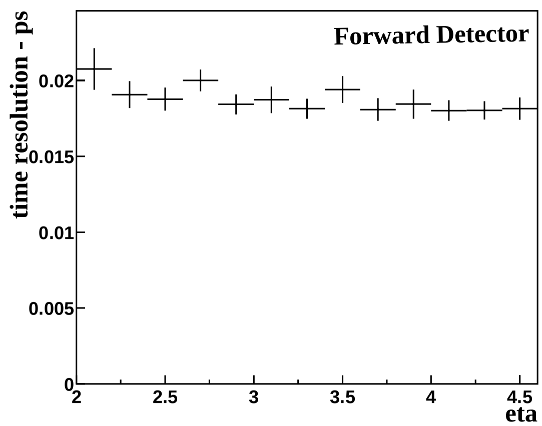


Figure 3: Normalized Decay Length L/σ for $B^o \to \pi^+\pi^-$ for Forward and Central Detector



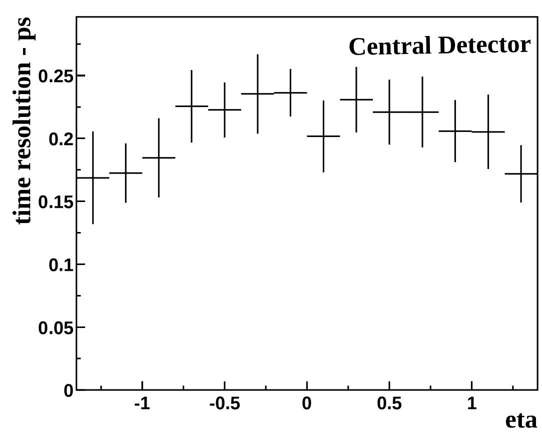


Figure 4: Time Resolution Plotted as a Function of η for a Forward Detector $2.5 < \eta < 4.5$ and a Central Detector $1.5 < |\eta|$ for the Decay $B_s \rightarrow \psi K^*$.

Other important advantages of forward detectors include enough longitudinal space to include a highly efficient particle identification device with good K/π rejection along with electromagnetic calorimetry and muon detection. Since less physical area is instrumented, costs can be substantially less than a central detector.

4 The Proposed C0 Detector, the R&D Program, and Its Relation to BTEV

4.1 Central Dipole

After a long study, BTEV chose as its baseline spectrometer configuration a dipole centered on the interaction region, referred to as the 'central dipole' geometry. The central dipole configuration is a very compact way of achieving forward coverage on both sides of the IR. The prototype detector requires a dipole centered on the C0 interaction region. This dipole will be an existing dipole which will be available after the completion of the Fixed Target run in 1998. The two best candidates are the magnet called SM3 currently operating in the Meson East beam for E866 and the dipoles operating in the Wideband Beam for E831 (or a very similar magnet formerly used in E706, which has a larger aperture). We are beginning to study how these magnets, neither of which is the ideal magnet for the final experiment, will perform in the C0 setup.

4.2 Silicon Tracker

The silicon tracker – vertex detector is the heart of the BTEV experiment and will be the focus of many of the activities in C0. The tracker must be capable of separating secondary vertices from the interaction vertex with high efficiency and do so in a way that can be incorporated into the trigger at the lowest level. We do not yet have an optimized design for this detector. It will most likely consist of silicon strips and pixels.

Pixels will almost certainly be needed in the final BTEV experiment and are a major thrust of the C0 R&D program. Three independent reasons justify the use of a pixel detector in this experiment, at least in the region near the beam:

- The occupancy in the forward region prevents us from using only microstrip detectors.

- By virtue of their small surface, pixels have much smaller capacitance then microstrips and (therefore better signal to noise ratios), allowing us to sustain higher radiation damage

- Pixels provide 3-dimensional space points without having to reconstruct hit information from individual 2-dimensional devices (strips), greatly facilitating the reconstruction of the tracks in quasi-real time for the trigger.

The present design has a tracking station every 4 or 5 cm along the luminous region. Each station consists of three planar detectors. The detectors cover $\pm$ 5cm in both X and Y. Each of the three planes of a station consists of two sets of side by side 5cm$\times$5cm detector elements. One set is placed above the beam and one below it. The planes are mounted so that the vertical separation of the two halves can be varied. For data taking, the gap is $\pm$6mm between the active edges of the planes. For filling of the Tevatron, the detectors can be opened much wider.

The baseline silicon tracker currently contains hybrid pixel planes. A pixel size of 35 microns by about 130 microns is currently favored. The requirement that the data from the tracker be available for use in the first level trigger strongly affects the readout architecture of the pixels. We currently also plan to get a crude measure of the momentum of each track from the silicon tracker itself without the need to match to downstream elements. This leads to the requirement that we measure the pulse height on the pixels so that we can use a charge-sharing cluster algorithm to improve the resolution to about 6 microns. All these requirements are being studied and we hope that we can elimiinate or modify some of them.

We hope that the lab will undertake a program of pixel R&D aimed at satisfying the needs of the BTEV experiment (among others). We plan by the year 2000 to have a detector operating in C0 which would consist of silicon strips and some of the early prototype pixel planes which we could test under conditions very close to those of the final BTEV experiment. The tests would continue through a secoond and perhaps a third iteration of the detector in the years 2000 and 2001. The pixel design would then be finalized and production of the full detector for BTEV would begin.

Tests in C0 would consist of the most complete possible study of spatial resolution, vertexing, and triggering. We view the availability of colliding beams and of a dipole centered on the IR as being essential for these tests.

While the BTEV detector would cover most of the luminous region of the IR, the proto-type detector in C0 would start with a few planes to study the hit precision and would grow to at least 7-10 stations centered on the IR for trigger studies. More stations would be desirable if serious physics measurements are to be carried out.

While we expect the development of the final pixel system will require signifcant R&D, we have found one line of development which is currently underway to have many of the characteristics that we need for BTEV.

4.2.1 Description of the Data Push Architecture (DPA) Pixel

One possible design for the pixel planes is based on that developed by S. Shapiro and his collaborators[11] in 1993. The digital readout for these devices have been designed, fabricated and tested. They are DATA-PUSH, in that the hit pixel sends the data off-chip within nanoseconds, by having the hit pixel initiate the read-cycle. They allow low noise operation ($<$100e$^-$ rms), time stamping, analog signal processing, XY address recording, ghost elimination and sparse data transmission. They employ sampled data techniques for rugged system performance, and have a minimum of cross talk due to current mode output drivers. Comparator time-walk has been measured at $<$ 15 ns (from twice threshold to infinity), timing measurement consistent with a throughput of $<$ 200 ns per hit measured, and a power per pixel of about 24 μW.

These devices were designed with the needs of a forward spectrometer in mind, having been created for the SSC/BCD. Their small pixel size permits resolution matched to the needs of the desired displaced-vertex-trigger, and the DPA feature allows the information to be used as part of such a trigger.

The product of continuous development work since 1993, it is expected that a 16x16 array of 30x200 μm^2 analog readout pixels will be available in early Fall of 1996 for laboratory testing. The digital periphery of the array will have been completely designed, requiring only a few thousand dollars to be fabricated by MOSIS.

4.3 Downstream Tracker

The downstream tracker would consist of conventional straw tubes or drift chambers. A resolution of 200μm is adequate. This system, used in conjunction with the silicon tracker, will give the momentum and mass resolution necessary to isolate good signals for charm and bottom decays. This is essential both for trigger studies and for physics measurements. We believe that we can assemble a system from chambers and electronics recovered from the fixed target experiments that will be completed in 1998.

4.4 Vertex Trigger

Our baseline configuration for the vertex and displaced vertex trigger goes as follows: The vertex detector covers about 3 units of rapidity and can reconstruct tracks with an opening angle from 10 mrad. up to 300 mrad. In a collider mode, more than 20 stations separated by a 4-5 cm are required due to the longitudinal extent of the luminous region. This detector will clearly be much simpler - and cheaper - in a Fixed Target configuration, were all the events are coming from a wire running perpendicular to the beam. In a Heavy Quark experiment where fine spatial resolution is necessary to select secondary vertices and ultimately to get high acceptance after background rejection, it necessary to move as close as possible to the beam .

At a luminosity of 2×10^{32}, corresponding to 10 Mhz interaction rate, the charm rate is 500 khz and the B rate is 10 Khz. The fraction of reconstructable B^o could be as high as 30% (depending of the decay mode) (The ratio of heavy quark production to the total cross section is much lower for the Fixed Target option, however, the algorithm used to compute the detachment criteria are simpler, as the luminous region is very well defined) A programmable trigger based on displaced vertex is preferable to other options (such as average transverse momentum, high Pt leptons,..), because it is unbiased and most efficient at obtaining a large and reconstructable sample of heavy quark decays.

The implementation of a silicon based trigger , at the lowest level, requires the use of Data-Push architecture described above. Such architecture provides on a data driven, sparsified readout scheme at high speed.

The trigger processor, ultimately capable of processing up to 100 Gbyte of raw data per second, is based on three levels. The total interaction rate is about 10 Mhz. The present plan is to employ enough parallelism and pipelining to provide about 256 beam crossings, or about 34 microseconds, for the Level 1 trigger. The pixel detector is divided into mini-areas both longitudinally and azimuthally with each little sector having an occupancy of less than one track on the average. Individual front-end electronics and processors perform the trigger operations on each sector in parallel. Routers, switches, and FIFO buffers deliver the data to inexpensive processors. The trigger uses the pulse heights from the from the pixel detector to first form clusters and then tracks. By using the pulse height to improve the resolution by taking advantage of charge sharing, the pixel detector can provide a crude momentum measurement for each track. A vertex algorithm is them applied to those tracks whose transverse momentum is above some modest value to form a primary vertex and to locate tracks with large impact parameters relative to it. Events with two or more tracks having large impact parameters are passed to subsequent levels of the trigger. These steps will reduce the overall rate to less than 100 Khz. The Level 2 trigger will match the silicon tracks to the downstream tracking system providing a much better measurement of the momentum. A more sophisticated vertexing algorithm will be used to find secondary vertices and measure their distance from the primary. Mass cuts on the secondary vertex can also be applied at this level. This will reduce the event rate to a few Khz. The events will then be sent to a Level 3 processing farm where they will be further analyzed and reduced essentially to DST form – about 20 Kbytes per event. About 1000 events per second will be written to archival storage for subsequent analysis. The total data rate will be about 20 Mbyte/second. About 200 Tbyte/year of DST data will be accumulated for subsequent analysis.

For the tests in C0, we will probably need, in addition to the prototype BTEV vertex trigger, a rather simple muon trigger which can be used as an independent trigger (along with a pre-scaled minimum bias trigger) for calibrating the vertex trigger's efficiency and rejection.

4.5 Muon System

The muon system will be used to provide triggers for charm and beauty enhancement and for searches for rare and SM forbidden decays. In addition, it will enable us to measure the muon background in the forward direction in the collider. The system will provide single and dimuon triggers, as well as a J/ψ trigger (that selects proper dimuon masses). The system will consist of a sandwich of 2–3 m of iron and three detector layers. We are considering several technologies for the final BTEV detectors, including cathode strip planes and resistive plate chambers. For the test setup in C0, we would try to make use of existing detectors. Candidates are muon systems from E665, E687, or D0. We are in the process of understanding the rates in the collider which will certainly influence this choice.

The muon steel for C0 will be obtained from fixed target experiments which will have completed their run by the end of 1998. The transverse size of the detector will be approximately ± 3.5m horizontally by ± 2m vertically.

4.6 Particle Identification System

The BTEV detector requires particle identification to be an effective physics instrument. While several types of Ring Imaging CHerenkov detectors appear to be able to provide the requisite efficiency and rejection power, the actual choice needs to be determined after a considerable R&D effort. Two Cherenkov radiators are necessary in order to cover the momentum range of B decay products, 1-70 GeV/c. In Fermilab Test Beam proposal T880 we show how a system based on "sawtooth" LiF radiators, for low momentum, and C_2F_6 gas, for high momentum, coupled with CLEO III style photon detectors could provide the detector configuration needed. It is also possible that a DIRC based detector would take much less space than the LiF, and be faster being phototube based. For the gas radiator, we also need to investigate the possiblilies presented by working in the visable rather than uv range using hybrid photodiodes or multianode phototubes. This could provide a better resolution, more flexible and faster photon detection system.

In C0 we may be able to use the threshold Cherenkov counters used currently in E831. Investigations of their utility are now underway.

4.7 Other Possibilities

The detector described above emphasizes tracking, vertexing, and particle identification. These are there areas where significant R&D is necessary for the BTEV program. The muon detector provides a way of enhancing certain physics states to improve these studies. If one were undertaking a complete physics program, one would want also electromagnetic and hadronic calorimeters. This would increase the efficiency on semileptonic decays and might help the trigger for some short-lived charm states.

Another possibility would be to extend the downstream tracker and the muon detector to both sides of the IR. This would double the acceptance for B-decays. The BTEV experiment, of course, plans for full capability coverage of both sides of the IR.

5 The C0 Physics Program

We discuss the possibility of carrying out actual physics measurements with the C0 detector. Of course, much depends on the scale of resources which are available for constructing the detector. The numbers given below are for a full BTEV-like detector. The actual detector in C0 may cover only part of the IR, may have only one side instrumented, and may even lack completely particle identification. These numbers should be considered optimistic.

5.1 Charm Physics Program at C0

There are two motivations for pursuing charm physics in C0 in the context of developing the BTEV experiment:

- To perform high statistics trigger and detector R&D using the large samples of charmed mesons that will be produced; and
- To do a high sensitivity experiment to study rare and SM forbidden phenomena in charmed meson decays both as significant physics investigations and as a means of developing and refining our analysis techniques

The charm cross section at two TeV has not been measured but is calculated to be very large – about 1.2 millibarn or 2% of the total cross section. In a 'Snowmass year' of 10^7 seconds, the total number of charmed pairs produced is over 1×10^{11}. The number of reconstructed decays of $D^o \to K^-\pi^+$ or $D^+ \to K^-\pi^+\pi^+$ is expected to be around 5×10^8 without including the trigger efficiency or the particle identification efficiency.

This large supply of charm events can be used in a variety of ways to test and refine tracking and triggering algorithms based on vertexing since thousands of signal events can be obtained in a very short amount of time. Data can be accumulated with no trigger or with a simple charm enhancing trigger such as a muon trigger and the efficiency and rejection of the vertex trigger can be obtained. We expect to resolve many of the problems that will be encountered in trying to perform a precision experiment in the forward direction at the Tevatron.

In addition, a variety of physics topics can be attacked once the vertex trigger is working. These include the measurement of the charm cross section at collider energies and an investigation of rare and standard model forbidden decays. Since the charm quark is not expected within the Standard Model to mix readily and decays involving loops are also heavily suppressed, the observation of any of these signals would most likely indicate new physics beyond the SM. In addition, Direct CP violation is expected within the Standard Model at the level of a few tenths of a percent and it is just possible to approach such levels in an exposure at C0. Of course, the observation of a Direct CP asymmetry at a much higher level than this would again most likely be due to new physics. The BTEV experiment should actually be sensitive to CP violation at a level well below that predicted by the SM and the experience gained in this test run would be extraordinarily useful in helping us understand the issues involved in this very delicate and possibly systematics limited measurement.

There is also the possibility of studying collisions made by the anti-proton (or proton) beam halo on a wire target. We refer to this as 'Fixed Target' mode. This would be an excellent tuneup for the collider part of the running but would not test all the issues of interest. It is possible to obtain sensitivity for charm decay studies per unit running time in Fixed Target mode which is not too much worse (a factor of two or three) from collider running in C0. As an experiment, the Fixed Target configuration is probably not competitive with Hera-B (which we assume will also pursue charm physics) which will already be running, is designed to operate at much higher rates, and has a much more sophisticated and better instrumented detector. In our view, the collider version of the experiment is a learning experience for the full BTEV experiment which would eventually be able to surpass anything Hera-B could do by a large margin. We therefore aim at collider charm physics in C0.

5.2 B Physics

The proposed experimental setup in C0 is designed to provide the oppportunity to develop the sophisticated tracking and triggering needed by the BTEV experiment. There is no better way to prepare for BTEV and to validate the technical approaches that have been taken than to undertake some limited B physics explorations. Even if they are not competitive with the first round of experiments, which might by then just be hitting their stride, they will provide excellent experience.

Assuming that C0 has a central dipole with a prototype silicon tracker, a downstream straw, drift, or PWC system, a muon filter and muon detector, and some triggering and data acquisition gear, we can acquire a reasonable samples of B decays when operating in collider mode where the B cross section is around 50 μb. (There is no hope of competing with Hera-B in Fixed Target mode unless the detector is as sophisticated as the Hera-B). Assuming a luminosity of 10^{31}, C0 will see about 5×10^9 $b - \bar{b}$ per year of operation. States like $B^o \to \pi^+\pi^-$, ψK_s, and ψK^* will be observable. In a year, according to our simulations, about 5×10^3 $\pi\pi$ events and a similar number of ψK_s will be accepted by the detector and are potentially reconstructable. If the BTEV trigger works as expected, the efficiency for triggering these states will be high. We do not know what kind of particle identification we will finally have so we cannot say whether we will be able to separate $\pi\pi$ from πK and KK final states. The observation of these signals will result in good measurements of the B cross section in the forward direction. It is unlikely (but not impossible) that they will be competitive with other measurements available at that time, but they will provide an excellent existence proof of the techniques that will be employed in BTEV.

6 Summary of Requests for C0 Area, Detector R&D, and Equipment

Above, we have outlined our plan to use the opportunity presented at C0 to develop the BTEV experiment. We have also indicated which physics investigations could be carried out in that area with a reduced detector configuration. Here we summarize the requirements on the C0 area for this program, our requests for R&D to be carried out under the leadership of

FNAL, and our plans for obtaining equipment from existing sources.

6.1 Requirements on C0 area

- Enough transverse and longitudinal space to house the propsed version of the setup. We need at least 30 feet of space along the beam from the center of the IR to the wall to accommodate the instrumented side of the detector. We need at least 15 feet on the other side of the IR to accomodate the central dipole and to permit us to remove the vertex detector from this end. We strongly urge the lab to make the IR symmetric since that leaves the possibility of eventually doing the full BTEV experiment in this area should that turn out to be desirable. Thus, we believe that the current C0 enclosure dimensions of ± 30 feet by ± 36 feet by -7.5 feet$+$ >7.5 feet is adequate for this proposal. We would very much like to see the length of the enclosure increased to 80 feet but understand that funding considerations may make this impossible.

- We strongly desire to have colliding beams of reasonable luminosity, of order 10^{31} as early as possible, preferably by the year 2000. This means that we request that the lab pursue the acquisition and installation of magnets to achieve a reasonably low beta in this region. The key to learning how to do the experiment and to get a head start on developing the analysis depend on having an arrangement in C0 which approximates the final experimental setup. While some issues can be resolved by running on wires in the beam halo, many issues depend on dealing with the actual distribution of of signal and background events in the collider environment. The actual amount of running time in collider mode can be adjusted based on the total machine luminosity which is available, the ability of the other collider experimetns to use it, and the progress of the program at C0.

6.2 Detector R&D

There are three areas of detector R&D which are critical for the BTEV experiment and are the focus of most of the activity in C0. We request that the lab support work in each area which will address the requirements of BTEV. These three areas are:

- Pixels: Here we require detectors that can provide the track information for use in the first level trigger. These requirements have been incorporated in the recent survey conducted by Jeff Spallding.
- Trigger R&D: We need continuation of the work described in the BTEV trigger conceptual design.
- Charged Particle Identification: The problem of designing a suitable ring imaging Cerenkov counter and its readout is a demanding one. R&D into system design, the properties of materials, and work on readout is required.

6.3 Equipment Requirements and Sources

- A dipole centered on the IR. The dipole would either be the SM3 magnet from the M-EAST area, which can be reconfigured in a variety of ways or one of the E687/831 dipoles. Other options, such as using the E706 coils (which are stored in M-EAST) in the SM3 steel, also exist. These magnets give a lower integrated field than the baseline BTEV magnet but would suffice for the trigger test. Moreover, we have not yet optimized the BTEV magnet layout. A total P_t kick of close to 1 GeV/c and an iron length of at least 1.5 meter is required.
- A silicon tracker consisting of at least enough elements to accept approximately half of the effective luminosity. We request that some significant number of elements be pixel detectors meeting the BTEV specifications, which have been presented to the lab's working group on pixel R&D. We estimate that one pixel plane in the middle of each of 7 clusters would be adequate to accomplishing the first part of the proposed tests. These would be enclosed in a vacuum containment vessel. Readout electronics for the strips and pixels would need to be provided. This is probably all new equipment.
- A muon filter consisting of approximately 3 m of steel with three gaps for the insertion of detectors.

- Prototype trigger electronics for the vertex trigger. This is also probably new electronics but much of the development has already been completed.

- A data acquisition system which would be assembled out of components of the DART system which would be recovered from completed Fixed Target exerpiments.

- A downstream tracking system consisting of drift chambers, PWC's, and/or straw tubes recovered from existing experiments. We would also use the front end electronics from existing experiments.

- Active elements for the muon detector, most likely drift chambers, recovered from completed experiments. This would include reuse of front end electronics.

- The particle identification system. We are investigating the reuse of some of the components from completed experiments. Such a system may not be strictly necessary for trigger tests using charm in the collider mode but will be necessary for charm physics using a wire target or in collider mode. Some B studies such as those involving states with J/ψ's do not require particle identification. States such as $B^o \rightarrow \pi^+\pi^-$ certainly do require particle identification. More work will need to be done to understand what kind of detector is needed.

These detector requirements are a minimum set needed to carry out the trigger studies and some physics investigations in the C0 area. If one wanted to expand the physics objectives, one could add calorimetry – both EM and hadronic. One could also increase the acceptance by covering more of the IR with silicon or by instrumenting both sides of the IR – at least partially.

References

[1] "The Physics Program of a High-Luminosity Asymmetric B Factory at SLAC," SLAC-353, Oct. 1989, p83; K. Abe et al., KEK Report 90-23.

[2] Penguin pollution in $\pi^+\pi^-$ is discussed by M. Gronau, Phys. Rev. Lett. 63, 1451 (1989).

[3] An updated SLAC analysis is given by P. Harrison in 'Beauty 95', ed. N. Harnew and P. E. Schlein, NIM A368 (1995) p86; see also ref [3] p57 for more pessimistic estimates.

[4] Since the $\rho^+\pi^-$ and $\rho^-\pi^+$ final states are not CP eigenstates a deconvolution must be performed to extract α. This may involve a luminosity penalty if the the amplitudes differ and leads to a two fold ambiguity. See R. Aleksan et al., "CP Violation Using non CP Eigenstate Decays of Neutral B Mesons," Saclay preprint DPhPE 90-17 (1990) or ref. 5 p58.

[5] K. Lingel et al., "Physics Rationale For A B Factory," CLNS 91-1043, June 1993, p89.

[6] R. V. Kowalewski et al., in 'Beauty 95', ed. N. Harnew and P. E. Schlein, NIM A368 (1995).

[7] P. McBride and S. Stone, in 'Beauty 95', ed. N. Harnew and P. E. Schlein, NIM A368 (1995), p38.

[8] J.N. Butler, in 'Beauty 95', ed. N. Harnew and P. E. Schlein, NIM A368 (1995), p145.

[9] M. Gronau and D. Weiler, PLB 265 (1991) p172.

[10] S. L. Stone, NIM A333 (1983), p15.

[11] SLAC-PUB-6249

[12] FERMILAB-CONF 95/170.